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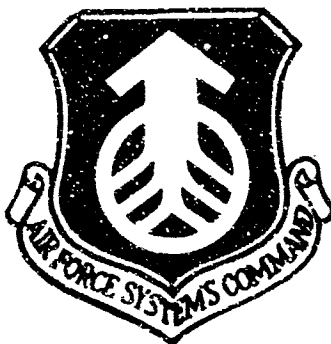
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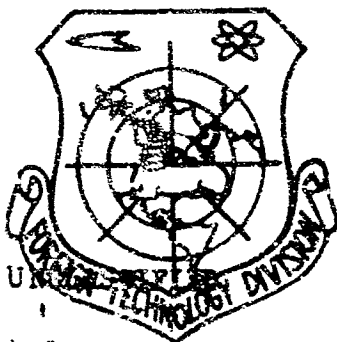## THIS PAGE IS UNCLASSIFIED

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FOREIGN TECHNOLOGY DIVISION

CHARACTERISTICS OF VERY HIGH FREQUENCY AND ULTRA HIGH FREQUENCY
DIRECTIONAL ANTENNAS AND THEIR MEASUREMENT

by

E. Spindler

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UNEDITED ROUGH DRAFT TRANSLATION

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By: E. Spindler

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ABSTRACT: Certain phenomena associated with the radiation characteristics of directional antennas, of particular practical importance in communications engineering, are carefully defined and dealt with in detail. In the measurement of the radiation characteristics, only the coaxial system (60-Ω-coaxial cable) is used, as this gives the smallest error, and in the measurement of the directional diagram only the normalized diagram is taken, as the normalized representation is generally valid. English translation: 11 pages. Orig. art. has: 3 formulas, 1 table, and 7 figures.
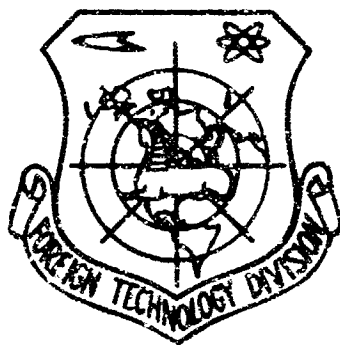
CHARACTERISTICS OF VERY HIGH FREQUENCY
AND ULTRA HIGH FREQUENCY DIRECTIONAL ANTENNAS
AND THEIR MEASUREMENT

E. Spindler

The Radiation Characteristics

The Radiation Characteristics as the Characteristic
Value of an Antenna

When we speak of the radiation characteristics we are speaking of the general characteristics of the electromagnetic field that is produced by an antenna in space. For the most part we consider in this connection the distribution of electrical field strength or the distribution of the radiation density (output of each surface unit) of the radiation power. The most comprehensive representation is the radiation characteristic, this can be calculated by a linear super-position of the radiation from the elementary radiator, of which each antenna is basically composed. The radiation of the elementary radiator that is in question is well known. Even so, antennas with well known radiation characteristics can be considered as elementary radiators, e.g., in the calculation of antenna groups.

Specific characteristics of the radiation characteristics are of considerable importance in practice and for this reason they are defined more closely and special attention will be paid to them in the following article.

The Radiation Characteristic

The radiation characteristic is also often designated as the directional characteristic. In receiver antenna technology it is represented for the most part, depending on the value (it is generally complex), in spherical or in a rectangular spatial coordinate system. In this connection, however, only the relative radiation characteristic is practical, i.e., this radiation characteristic is standardized on the maximum value of the field strength and in so doing we obtain the standardized directional characteristic

$$\frac{E}{E_{max}} = f(\theta, \psi)$$

in which θ and ψ is the angle of the spherical coordinate system.

When we speak of the radiation diagram (or directional diagram) we generally think of an arbitrary section through the radiation characteristic, in connection with which, however, the end point of the directional vector describes a circle on the unit sphere.

If the section goes through the radiation characteristic in the vertical plane and if it obtains the main radiation direction then we talk generally of a <u>vertical diagram</u>; if it is in the horizontal plane and receives the main radiation direction then we talk of a <u>horizontal diagram</u>. This also holds true for the corresponding standardized diagram. This is exclusively based on the following. From the standardized representation all the characteristic values proceed in a simple manner.

In order to characterize the directional diagram of an antenna clearly, independent of the polarization of the antenna, we often base the diagram on the polarization direction when we are dealing with linear polarization which is the case in this relationship. We then speak of a diagram of the E-plane or H-plane, abbreviated simply as E or H diagram.

In connection with horizontal polarization, for example, the horizontal is identical to the E diagram and the vertical with the H diagram. The diagrams are shown in connection with television receiving antennas in the linear scale.

Gain

The gain of an antenna is generally given the most attention and also the most important characteristic magnitude.

Since an antenna, however, is a passive system, the gain can be determined primarily by the direction characteristic. That is to say, therefore, the increase in radiation density in a certain direction takes place at the cost of the radiation density in another direction. This is accompanied by an immediate relationship between the gain and radiation diagram.

The gain in receiver antennas is defined as the ratio of the power P_a from the matched antenna to the maximum power given to the receiver to power P_N which is given from a matched comparison radiation to the receiver when the comparison radiation is in the same field as the same field strength of the antenna and when it is of the same polarization.

$$G = \frac{P_a}{P_N} \quad \text{or} \quad G = 10 \lg \frac{P_a}{P_N} \text{ in dB}$$

If the receiver resistance is the same then the gain also corresponds to the ratio of the voltages and is expressed as

$$G = \frac{U_a^2}{U_N^2} \quad \text{or} \quad G = 20 \lg \frac{U_a}{U_N} \text{ in dB.}$$

The ratio U_a/U_N is often designated as the "voltage gain". This designation is, however, not exact since the gain is always a performance ratio.

The following a e thought of when we speak of comparison radiators: the spherical radiator, the elementary dipole and the half wave dipole.

In Table 1 we see the relationship between the gain value of this comparative radiator.

In television receiver antenna technology the gain is usual? based on a matched half wave dipole, thus, the antenna need not be matched exactly only the reference resistance is given (240 Ω).

These are, therefore, the conditions that occur in practice. Correspondingly, this gain is designated as the practical gain (working gain). This definition is, therefore, to be taken into consideration when speaking of gain.

If we consider an antenna as loss free and if we attribute the gain to a loss free matched spherical radiator according to the general definition, then this gain is designated as the radiation gain (gain, directivity).

The elementary dipole when used as a reference radiator in this relationship does not have a practical meaning.

Standing Wave Ratio (SWR)

In TV receiver antennas SWR means the ratio of the voltage that occurs from the receiver resistance — when the antenna receives from the main radiation direction — to the voltage at the receiver resistance — when the antenna is turned $180°$ to the receiving direction.

$$VRV = \frac{U_o}{U_{180}} \quad \text{or} \quad VRV = 20 \lg \frac{U_o}{U_{180}} - \text{in dB}$$

The logarithmic value is designated as the front to back ratio. In this connection it must be pointed out that this definition cannot be used uniformly. Often the voltages set by adjusting the antenna

with the main receiving direction to the transmitter in ratio to an average value from the main receiver direction the rearward angle range is set between 90 and 270°. This value does not, however, allow any exact conclusion to be made of the directional effect of an antenna. In the definition that we have, however, the front to back ratio is exactly for the entire angle that was determined (0°/180°). In combination with other characteristic values a better statement is therefore possible.

Aperture Angle

The directional characteristic of an antenna contains the so-called main radiation lobe in its main radiation direction. By means of it the characteristics in the vicinity of the main radiation direction are determined. The form and size of the main radiation lobe is characterized in an approximate manner by the aperture angle. That is the angle range in a plane in which the voltage that is given off by the antenna is reduced by $1/\sqrt{2}$ times (0.707 times) of the maximum voltage (in the main radiation direction).

At the same time the angle range in which the output that reaches the receiver decreases by one half. For this reason this angle area is also designated as the half value width.

Corresponding to the characteristic section through the directional characteristic, this angle is given for the horizontal and vertical diagram (or E and H plane).

Table 1
Gain Relationships in Connection with Various
Comparison Radiators

1) Bezugsstrahler	2) Isotropstrahler	3) Elementardipol	4) λ/2-Dipol
Isotropstrahler	G = 1 (0 dB)	G = 1.5 (1.76 dB)	G = 1.64 (2.15 dB)
Elementardipol	G = 0.666 (−1.76 dB)	G = 1 (0 dB)	G = 1.09 (0.39 dB)
λ/2-Dipol	G = 0.61 (−2.15 dB)	G = 0.91 (−0.39 dB)	G = 1 (0 dB)

KEY: (1) reference radiator; (2) isotropic radiator; (3) elementary dipole; (4) λ/2-dipole

Zero Position

The zero position is indicated as the position in the diagram in which the voltage or power decreases to the zero value. Zero positions as such are given with their angles.

They occur when, in antennas the sum of all the discrete radiation parts result in the zero value taking the counter phase length into consideration.

The possibility of the zero position occuring increases with the number and expansion of the spatial arrangement of the elementary radiator in which every antenna can be analyzed.

Side Lobe Attenuation

Next to the main lobe in large antennas so-called side lobes also occur. As was already mentioned the directional diagram of each antenna occurs as a linear superposition of all the radiations of discrete elementary radiators in which each antenna is made up. The optimal phase position of these radiations make up the main loop. By means of the various radiation directions and the spatial distribution of the elementary radiator there is a definite phase ratio for each radiation direction which in addition to the amplitude determines the sum vector. As already mentioned the main radiation loop occurs, the zero position, as well as additional maximal and minimal values of the total radiation.

The maxima beyond the main radiation loop between the minima or zero positions are designated as the side loops. Generally, they are undesirable. The logarithmic ratio of the maximal voltage value of the main loop (U_{max}) and the maximum value of the side loop (U_{Nmax}) is designated as the side loop attenuation d_n.

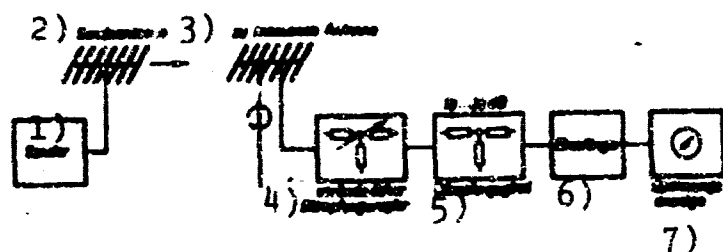$$d_n = 20 \lg \frac{U_{max}}{U_{Nmax}} \quad \text{in dB}$$

Fig. 5. Test arrangement for measuring the diagram.
KEY: (1) transmitter; (2) transmitting antenna; (3)
antenna to be measured; (4) variable attenuation
regulator; (5) attenuation element; (6) receiver;
(7) voltage indicator

In order to give exact data on the side loop attenuation the angle is required at which the maximum of the side loop appears.

Measuring the Radiation Characteristics

Two systems are required as the energy transmission transmitting systems in television receiving antenna technology: the symmetrical system (240 Ω ribbon twin conductor) and the coaxial system (60 Ω coaxial cable).

In measuring, the coaxial system is used exclusively, because the lowest amount of errors are obtained with it. These errors occur, for example, by unwanted rays that strike the cable and the measuring instrument (symmetry error), as well as the influence of matching.

In measuring symmetrical antennas symmetry elements with optimal characteristics are used (e.g., λ/2-bypass).

Measuring the Directional Diagram

As was already mentioned the standard representation is that of a generally valid expression. For this reason the standardized diagram is used for the most part. This means, therefore, that the maximum

value of the voltage that appears on the receiver resistor (in the main radiation direction of the antenna) has the standard value of 1. In practice the diagram takes a E and a H plane. It shows the voltage as a function of the horizontal or vertical angle. The angle zero is attributed in both cases to the main radiation direction (main receiver direction).

An antenna is for the most part measured as a receiving antenna, in which the field is produced by a suitable transmitting antenna with a receiver that gives the desired frequency. The receiver antenna is arranged in such a way that it can be turned and the power is transmitted to a receiver. Basically, any selective receiver can be used as the receiver which has a linear voltage indicator or which is suitably calibrated.

In order to realize the required matching at the receiver input in every case an attenuation element that is wave resistance free with an attenuation of about 10 to 20 dB is connected in front of the receiver.

The fundamental construction is, thus, as shown in Fig. 5.

Any standard receiver can, generally, be used to receive the directional diagram. The linearity of the representation is pointless to control because we connect an attenuation element between the antenna cable and the receiver of, for example, 3 dB, 6 dB, and 20 dB. In this connection the indicated voltage must return consecutively from $1/\sqrt{2}$ times, 0.5 times and 0.1 times. If this condition is fulfilled, then the directional diagram can be recorded in the linear scale with this arrangement in which the antenna is set to the corresponding angle (in intervals of about 10 to 20°) and the corresponding test value is represented in a polar diagram or in cartesian coordinates. The test receiver that is used can, in this case,

have any automatic amplification control. If there is one like that
it must then be turned off. An external voltage is conducted in a
random manner as a control voltage which can be adjusted with regard
to its magnitude, manually. In so doing the amplification of the
receiver can be regulated in such a way that the maximum value 1 can
be adjusted on the indicating instrument that is available by a value
of 1, 10, etc. and in so doing we find that it is very easy to read.
The simplest measurement is when the horizontal polarization is
selected for the E plane diagram and the antenna is correspondingly
rotated horizontally when it takes the directional diagram. In taking
the directional diagram of the H plane, vertical polarization is
selected appropriately and the antenna is turned horizontally.

In plotting the directional diagram, certain test errors could
appear by receiving the gnal from several directions.

A possible case is shown in Fig. 6 in which the antenna is
radiated from an angle 60° and the main loop receives an additional
reflected signal. The voltage that is indicated by the test instrument
is, however the total voltage of both signals taking the counter
phase position into consideration. That means that both signals can,
in an extreme case, be added or subtracted. The possible error of
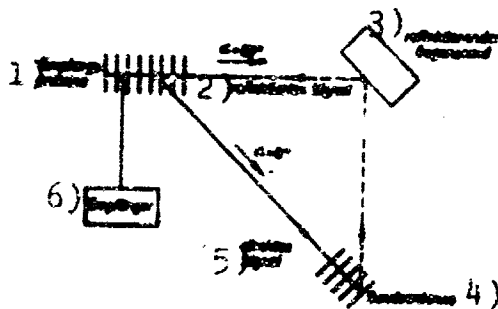the diagram is shown in Fig. 7.

Fig. 6. How an error occurs in measuring a diagram.
KEY: (1) receiver antenna; (2) reflected signal;
(3) reflected object; (4) transmitting antenna; (5)
direct signal; (6) receiver

This error occurs especially when small values are to be measured or when in the diagram there is a zero position. In connection with zero positioning a so-called zero position mark is attained.
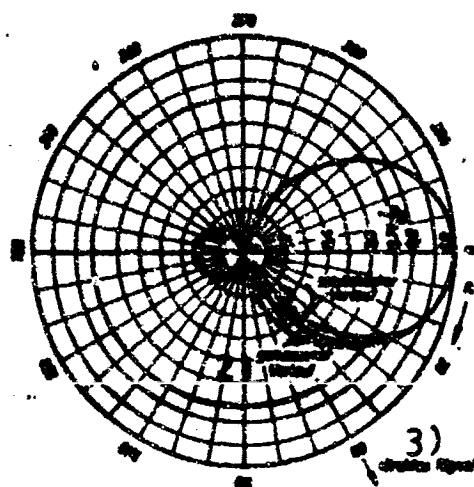

Fig. 7. Effects of measuring errors in the diagram (loop formation with zero position mark).
KEY: (1) actual pattern; (2) measured pattern; (3) direct signal

This situation is to be observed especially in the zero position of the diagram of the E plane of dipole antennas at $90/270^\circ$.

Reflected signals, for the most part, result in a distorted field due to their phase difference in comparison to the direct signal. The best way, therefore, to convince oneself as to whether the field varies only within certain limits, is before the measurement is made. A variation of the electrical field strength of 0.5 to 1 dB is considered as a permissible error. This control is carried out with a $\lambda/2$ test dipole. In this relationship the voltage of the testing dipole can vary by the value indicated.

In receiver antennas the diagram pattern is shown up to about 26 dB under the maximum value (main loop). That is 1/20 of the maximum value and smaller values of the diagram are not recorded exactly. This accuracy is sufficient for practice.

## Nomogram for Determining Grounded-Anode Stages

The following nomogram that is described is used to simplify the measurement of grounded-anode stages that are used as impedance transformers. The grounded base stage, or also the cathode sequence stage, has a low ohmic output and a high ohmic input.

Example: A circuit with a ECC 82 is given.

The magnitude of the resistance R_o is sought when the output impedance is to be 60 Ω transconductance of the tube is to be 2.2 mA/V.

A straight line (broken line) is drawn from the value of the transconductance to the value of the desired output impedance. The section on the R_o-ordinate gives the desired value in this case 68 Ω.
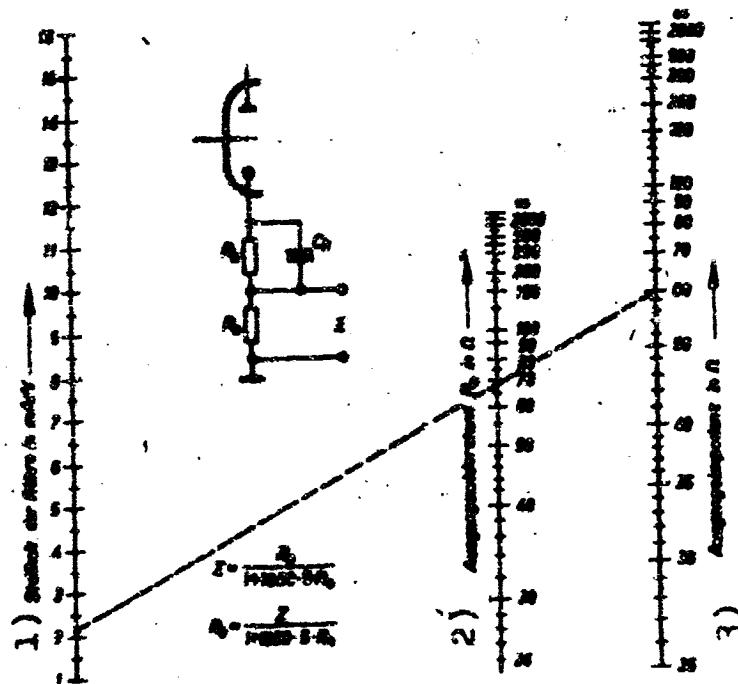
KEY: (1) transconductance of the tube in mA/V; (2) output resistance; (3) output impedance